AD-047581

WADC TECHNICAL REPORT 54-116

# DEVELOPMENT OF HYDRAULIC HOSE, SIZE 8 CONFORMING TO SPECIFICATION MIL-H-5017


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*January 1954*

Aircraft Laboratory
Contract No. AF 33(038)-22904
RDO No. 452-495B

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio


Carpenter Litho & Prtg. Co., Springfield, O.
100 - 23 November 1954

NOTICE

## FOREWORD

The work described in this report was accomplished by the United States Rubber Company, Passaic, New Jersey for the Wright Air Development Center, Wright Patterson Air Force Base, Ohio as authorized by Contract No. AF 33(038)-22904 dated 23 March 1951, RDO 452-495B (UNCLASSIFIED), Elastomer, Plastic, and Fluid Components. The contract was administered under the direction of Lt. R. E. Lyons and Mr. F. R. Straus of the Aircraft Laboratory, Directorate of Laboratories, Wright Air Development Center.

Chief responsibility for the conduct of this program was assigned to Mr. T. D. Ernst. Others who contributed to the successful completion of the work included: Mr. R. J. Meisinger of the United States Rubber Company and Mr. R. W. Phillips of the Weatherhead Company, Cleveland, Ohio.

ABSTRACT

A study of wire braided hose manufacturing techniques, materials, and design has been made to establish principles necessary for the manufacturer of hose to meet the requirements of Specification MIL-H-5017 size -8.

The design and manufacturing techniques used to produce a -8 size hose sample which met all the requirements of Specification MIL-H-5017 is described.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings or the conclusions contained therein. It is published only for the exchange and stimulation of ideas.

FOR THE COMMANDER:

E H Schwartz
for D. D. McKEE
Colonel, USAF
Chief, Aircraft Laboratory
Directorate of Laboratories

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## OBJECT

Development of high pressure hydraulic hose, size -8, conforming to Specification MIL-H-5017, dated 13 February 1950.

## INTRODUCTION

The research work directed toward the development of hose to meet the stringent requirements of Specification MIL-H-5017, can be divided into three catagories, namely, the evaluation of materials, fundamental hose design, and analysis of processing techniques. A considerable portion of the work was concentrated on the latter phase. This was done on the basis of this company's experience with two wire braid high pressure hose. On several occasions in the past, samples of this hose, selected for quality braiding from production runs, were tested and found to meet the impulse requirements of this specification. Knowing that hose with exceptional braiding would meet these tests, it was believed that the materials and design being used were satisfactory and that the main problem concerned the improvement of manufacturing techniques to insure greater uniformity of quality. The final outcome of the work indicates that this was principally the case.

## SECTION I
## EVALUATION OF MATERIALS

### Hose Reinforcement Wire

Conventional hydraulic hose reinforcement wire is hard drawn high carbon steel wire usually produced in two tensile ranges, namely, 300,000 to 350,000 P.S.I. and 350,000 to 400,000 P.S.I. Sizes ranging from 0.008 to 0.016 in. diameter are customarily produced with a straw liquor finish. The liquor finish is an electrolytically displaced coating of copper and tin applied to the wire prior to its final draw. This coating is instrumental in producing a bond between the rubber and the wire.

The wire is sufficiently ductile to wrap around a mandrel, the diameter of which is four times the wire diameter, without showing signs of fracture.

Discussions were held with the technical personnel of several wire suppliers in an effort to learn more concerning the fundamentals of wire technology. Little information was gained through these interviews. All the technicians advised that the wire currently being furnished was, from a metallurgical standpoint, the best composition that could be offered. No compositions which would exhibit superior flex fatigue or ductility are known. It was further stated that no testing equipment is available with which reliable data on fatigue life can be obtained for the sizes of wire concerned. Wire fatigue testers using the rotating beam principle are available but test results obtained with these instruments are erratic.

It was apparent from these discussions that there is a sore lack of basic information on the physical properties of wire. It is the opinion of the investigators that there is a great need for research in this field. Until the fatigue life of hose reinforcement wire can be improved or at least measured with a reasonable degree of accuracy, the element of trial and error will never be eliminated from the design or manufacture of hose for high impulse service.

It was generally recommended that the greatest flex or impulse life would be obtained by using the highest tensile wire available and building the highest burst strength possible into the hose.

All the wire manufacturers were of the opinion that 400,000 P.S.I. was the maximum tensile strength. Their experience with harder drawn wire indicates that minute flaws not apparent in a lower tensile range become greatly exaggerated above 400,000 P.S.I. causing considerable non-uniformity. It is possible to draw .008 inch diameter wire to 425,000 P.S.I. or possibly higher without encountering this condition but on .012" and larger diameters, it is not recommended.

Two special types of wire were suggested as possible answers to improved impulse life; Swedish steel wire and Aircraft cord wire. Orders were entered for these materials but, unfortunately, delivery was made only a short time prior to the expiration date of the contract and insufficient time was left to produce samples.

Since that time trials with these wires have been made. Test results on hose made using these special wires are shown on page 9. Results show no improvement in impulse over the standard commercial wire. A design was developed using commercial hose wire in the 350,000 to 400,000 P.S.I. tensile range which meets the impulse requirements of Specification MIL-H-5017 with a considerable margin of safety. It was concluded from this work that certain design features must be adhered to in order to obtain satisfactory impulse life with any type of wire. Commercial grade hose wire appears to be entirely satisfactory provided it is incorporated into the hose properly.

## Tube Compound

The first few samples of hose were made using a standard tube compound BN-4636 which is a 75 ± 5 durometer freeze resistant Buna N compound having the following physicals:

BN-4636

| | |
|---|---|
| Durometer | 75 ± 5 Shore A |
| Tensile | 1800 - 2000 P.S.I. |
| Elongation | 175-225% |

During the course of making hose samples using this tube, considerable difficulty was encountered with tube bulging during coupling application. The high crimp or compression necessary to hold couplings on this type hose at the high pressures involved puts an extremely high compression stress on the tube. As the coupling insert is screwed into the hose tube, this stress tends to drive the tube forward, forming a bulge.

In order to overcome this condition, a harder tube compound BN-40507-G-2 was developed. It was realized at the time that increasing the hardness of the tube might impair its freeze resistance but there appeared to be no alternative if the bulge tendency was to be eliminated. The physicals for this tube stock follow:

<u>BN-40507-G-2</u>

| | |
|---|---|
| Durometer | 85 ± 5 duro |
| Tensile | 2000-2200 P.S.I. |
| Elongation | 150-200% |

This tube compound was incorporated in one of the designs submitted (XH-1725). Freeze tests were conducted on this hose sample in accordance with both MIL-H-5512 and MIL-H-5017. The tube failed to meet the requirements of the latter specification when the air aged sample cracked on flexing at -65°F. The oil aged sample was satisfactory.

When tested in accordance with Specification MIL-H-5512 which allows a 72 hour preconditioning in MIL-O-5606 hydraulic oil at 100°F. after the seven days air aging @ 158°F., the hose met requirements.

Further work was conducted to develop a tube stock which would meet the MIL-H-5017 freeze requirements, yet not cause excessive bulging. A tube stock, 40507-G-3 was developed and incorporated in the final design submitted for test (XH-1940). This tube compound meets the freeze requirements of Specification MIL-H-5017. The physical properties of this compound are:

<u>BN-40507-G-3</u>

| | |
|---|---|
| Durometer | 80 ± 5 |
| Tensile | 1800-2000 P.S.I. |
| Elongation | 175-225% |

Recipes for the three compounds appear in Appendix I pages 21 and 22.

<u>Layer Compound</u>

Hose samples were made with both .016" gauge and .032" gauge layers between the wire braids.

Impulse tests run on samples identical except for layer gauge showed improvement where the heavier layer was used. Examination of impulse samples showed that the layer stock is exposed to considerable abrasion and grinding action during this test due to the movement of the wire. The heavier layer cushions or absorbs this movement and prolongs eventual wire to wire contact which causes rapid failure.

The final construction developed utilized an .032" gauge layer of compound M-4779. This compound has only average physicals due to its non-black loading but exhibits good wire adhesion properties which are necessary to prevent wire flare. The recipé for the compound is included in the appendix, page 22.

Breaker Ply and Cover Stock

All hose samples were produced using compound M-4650, a 60 durometer high grade Neoprene compound. This stock meets freeze requirements and is satisfactory in all other respects. The recipe for this compound is included in the appendix, page 22.

Initial samples were made without a breaker ply in the cover which is conventional wire braid hose construction. Subsequent failures on the fire resistance test, however, made it necessary to incorporate a cotton breaker ply in the cover. It is difficult to visualize but the cotton braid, even though it carbonizes almost immediately, tends to hold the charred cover on the hose during exposure to the flame where it provides some insulation. This action is significant enough to make a marked difference in the fire resistance of the hose.

Samples of hose without the breaker ply submitted to the fire resistance test, paragraph 4.5.3.8, Specification MIL-H-5017 failed after two minutes or less exposure to the flame. The construction incorporating an .016" gauge layer of M-4779 over the wire and an open cotton breaker ply between the layer and the cover successfully met the ten minute exposure to the flame without leakage in all cases.

However, there is one disadvantage to using a layer and breaker ply on this hose construction. The cover thickness allowed by the specification is .055". Using an .016" gauge layer and .026" diameter breaker yarn, the effective cover thickness left is approximately .025". This is hardly sufficient for satisfactory production operation. Unless the finished hose cover is ground to dimension, the hose probably will be consistently heavy in O.D. In order to eliminate the expense of grinding, and the possibility of exposing the breaker ply on occasion, it is recommended that the cover gauge be increased to at least .078". In addition, it is possible that the increased cover thickness may improve fire resistance.

## SECTION II
## HOSE DESIGN

Numerous samples incorporating designs utilizing variations in braid angle or pitch, ends of wire, sizes of wire, layer compounds, and layer thicknesses were fabricated. The production of these samples was rigidly controlled to eliminate all possible process variations which might affect the final results. From the test results on these samples, the following principles concerning reinforcement braid design have been established as being necessary for satisfactory impulse.

1. Minimum hose movement.
2. Wire packs no greater than 90%.
3. Wire diameter of .012" maximum (Size -8 hose).
4. Sufficient cushion between braids.

1. <u>Minimum Hose Movement</u>

The angle of application or pitch of the reinforcing braids conducive to consistent good impulse life is that angle which allows minimum movement of the hose under pressure. This angle was found by experiment to be approximately 56°. Hose with high movement (3-5%) was found to give erratic impulse results while hose having movement in the 0-2% range showed far more consistency.

The specification limits of ± 1-1/2% appear to be sufficiently confining to insure consistent impulse results in this respect.

Some typical test results showing the relation between hose movement and impulse life are shown below.

TABLE I — HOSE MOVEMENT VS. IMPULSE LIFE

| Sample # | Movement (%) | Impulse Life (cycles) |
|---|---|---|
| XH-9651-1 | -5.25 | 93,090 |
| XH-9651-2 | -4.76 | 89,433 |
| XH-9652-1 | -3.67 | 41,373 |
| XH-9652-2 | -4.52 | 51,560 |
| XH-9793-1 | -4.15 | 185,000 |
| XH-9793-2 | -5.54 | 93,010 |
| XH-9798-2 | -2.16 | 108,632 |
| XH-9798-2A | -2.60 | 79,380 |
| XH-9790-1 | 0.00 | 256,410 |
| XH-9790-2 | -0.07 | 312,820 |

2. Wire Packs No Greater than 90%

The percent wire pack or that fraction of available surface area covered with wire should not exceed 90% if consistent impulse results are to be obtained. Crowding in more wire for higher burst will sacrifice impulse life. This is believed due to the greater crimp created on the wire with resultant poorer flex life and greater abrasion between individual strands.

3. Wire Diameter of .012" Maximum

Experiments with .015" diameter wire indicate that, although a small advantage is gained in burst, the impulse life is sharply reduced. It is believed that designs incorporating the smallest diameter wire that can be utilized with a reasonable margin on burst will result in the longest impulse life. The premise is that this is due to the greater crimp created in larger diameter wire as it passes over and under adjacent strands in the braid pattern. This would be particularly true for equal wire packs and appears to hold true even for somewhat lower percent packs.

Following these general principles and using the hose design formulae shown, a final hose construction was established.

$$\text{Pitch} = \frac{\pi \ (\text{Md})}{\tan \measuredangle}$$

$$\text{Number Ends} = \frac{(\text{Min. B.P.}) \ (\text{Md}) \ (\text{Pitch})}{2 \ (\text{Sin} \measuredangle) \ (\text{Strength Wire}) \ (\text{No. Spools}) \ (\text{No. Plies}) \ (\text{E})}$$

$$\text{R} = (\text{Strength Wire}) \ (\text{No. Spools}) \ (\text{No. Plies}) \ (\text{No. Ends})$$

$$\text{Burst Pressure} = \frac{2 \ (\text{Sin} \measuredangle) \ (\text{R}) \ (\text{E})}{(\text{Md}) \ (\text{Pitch})}$$

$$\underset{(\text{Reinforcement})}{\%\ \text{Pack}} = \frac{(1/2 \ \text{No. Spools}) \ (\text{Wire ga.}) \ (\text{No. Ends})}{(\text{Sin} \measuredangle) \ (\text{Pitch})}$$

Where: Md = mean diameter of reinforcing braids (This was calculated as 0.658").

Strength of Wire = 40# per end for .012" dia. Spec. 15A wire.

E = Efficiency (This varies but 75% appears to be the average efficiency for this type hose construction).

<u>XH-1725</u> MIL-H-5017 Size -8 7/16" I.D.

Tube: BN-40507-G-2 Finished gauge .070"
Extruded 31/64" I.D. x .095" wall and semi-cured 15' @ 30# steam.

Cement: Wash with solvesso and apply 1 coat P-784 cement.

Wire Braid: .012" dia. spec. 15A wire, 7 ends, 24 S.M., 1-3/8" pitch, 41/64"O.D.

Layer: M-4779 .032" ga.

Wire Braid: .012" dia. spec. 15A wire 7 ends, 24 S.M., 1-3/8" pitch, 4-7/64"O.D.

Layer: M-4779 .016" gauge.

Breaker: 7/3 yarn, 1 end, 24 S.M., 1-3/8" pitch

Cover: M-4650 .040" gauge extruded 27/32" O.D.

Cure: Spiral Nylon Wrap — 60' @ 50# steam.

The design of this hose is based on using one average mean diameter for both braids. Calculations treating the braids individually indicate a negligible difference. The difference is smaller than that encountered when the hose dimensions vary within tolerance limits.

Substituting in the hose formulae we obtain:

| | | |
|---|---|---|
| (Average braid angle) | | $56^{\circ}$ 19' |
| Burst Pressure (@ 75% E) | = | 18,600 P.S.I. |
| % Pack (average) | = | 88.2% |

Hose was made to this specification using a conventional Reading Textile wire braider. However, all equipment was rigidly inspected prior to use and all elements were carefully controlled with respect to quality, dimension, etc. during the course of manufacture.

This hose met all the general requirements of the specification with the exception of the Cold Temperature Test ($-65^{\circ}$ F.).

Impulse.......... 200,000 cycles and still running when test was stopped.

Burst............ 17,500 P.S.I. average.

In view of the failure to meet cold temperature requirements with the XH-1725 sample, additional hose was produced using the 40507-G-3 tube compound. The balance of the construction was identical to XH-1725. Test results obtained on this hose at the Aircraft Laboratory WPAFB are shown below. This hose successfully met the requirements of the specification including impulse and cold temperature requirements indicating that hose can be made on conventional equipment and materials to meet MIL-H-5017 Specification.

Following is the test data covering subject hose—

TABLE 2 - QUALIFICATION TESTS - SIZE -8 (7/16" I.D.) CONSTRUCTION XH-1940 - SPECIFICATION MIL-H-5017

| No. | ID | OD | Para. 2.2.5 Con. | Fitting | Proof | Age | Impulse | Cold Flex | Leak Test | Burst | Coup. | Para. 4.5.2.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .4375 | .736 | OK | Aeroquip | OK | — | 100,000 | — | — | — | — | — |
| 2 | .4375 | .740 | " | Weatherhead | OK | — | " | — | — | — | — | — |
| 3 | .4375 | .731 | " | Aeroquip | " | Oil | " | — | — | — | OK | — |
| 4 | .4375 | .739 | " | Weatherhead | " | Oil | " | — | — | — | OK | — |
| 5 | .4375 | .740 | " | Aeroquip | " | Air | " | — | — | — | — | — |
| 6 | .4375 | .742 | " | Weatherhead | " | Air | " | — | — | — | — | — |
| 7 | .4375 | .741 | " | Aeroquip | " | Oil | — | OK | — | Unable to burst | OK | — |

| No. | ID | OD | Para. 2.2.5 Con. | Fitting | Proof | Age | Impulse | Cold Flex | Leak Test | Burst | Coup. | Para. 4.5.2.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | .4375 | .746 | OK | Weatherhead | OK | Air | — | OK | — | Unable to burst | — | — |
| 9 | .4375 | .748 | " | Aeroquip | " | Air | — | " | — | " " " | — | — |
| 10 | .4375 | .736 | " | Aeroquip | " | — | — | — | OK | 17,100 | — | — |
| 11 | .4375 | .741 | " | Weatherhead | " | — | — | — | " | 16,000 | — | — |
| 12 | .4375 | - | " | — | — | Oil | — | — | — | — | — | OK |
| 13 | .4375 | - | " | — | — | Oil | — | — | — | — | — | " |

Elongation & Contraction

No. 10 - 0 = 11-1/8"     3000 psi = 11-3/16" —  Change .0056%
No. 11 - 0 = 11-3/8"     3000 psi = 11-1/2" —  Change .0109%

NOTE.....No. 8 and 9 were conditioned before cold flexing according to Specification MIL-H-5512A, Para. 4.6.2.6.

Samples 1 thru 6.....Impulsed OK

No. 7 leaked at one fitting test at 13,800 psi )
No. 8 leaked at one fitting test at 11,600 psi ).....Cold flex tested
No. 9 leaked at one fitting test at 14,200 psi )

No. 10 hose burst 4" from fitting
No. 11 fitting blew off

Extra samples submitted for cold flexing 10/19/53

No. A...Air aged and cold flexed OK...Proof OK
No. B...Air aged and cold flexed OK...Proof OK

No. A...Burst...leaked at Weatherhead Fitting 12,600 psi
No. B...Burst...leaked at Weatherhead Fitting 12,400 psi

Samples aged 10-19 to 10-26, 1953, samples not conditioned.

TABLE 3 - IMPULSE RESULTS - LIFE TESTS

COMPARISON BETWEEN SWEDISH STEEL WIRE - AIRCRAFT CORD WIRE AND COMMERCIAL GRADE WIRE - ALL CONSTRUCTIONS SAME AS XH-1940 EXCEPT FOR WIRE.

| Sample | No | ID | Wire OD | Conc. | Fitting | Proof | Age | Impulse |
|---|---|---|---|---|---|---|---|---|
| XH-1940 | 1 | .4375 | .727 | OK | Aeroquip | OK | — | 247,721 |
| Commercial | 2 | .4375 | .732 | " | Weatherhead | " | — | 287,322 |
| Grade wire | 3 | .4375 | .729 | " | Aeroquip | " | Oil | 216,467 |
| | 4 | .4375 | .735 | " | Weatherhead | " | Oil | 265,877 |
| | 5 | .4375 | .738 | " | Aeroquip | " | Air | 323,492 |
| | 6 | .4375 | .729 | " | Weatherhead | " | Air | 240,528 |

| Sample | No | ID | Wire OD | Conc. | Fitting | Proof | Age | Impulse |
|---|---|---|---|---|---|---|---|---|
| XH-1956 | 1 | .4375 | .730 | OK | Aeroquip | OK | --- | 297,109 |
| Swedish | 2 | .4375 | .732 | " | Weatherhead | " | --- | 269,816 |
| Steel Wire | 3 | .4375 | .738 | " | Aeroquip | " | Oil | 329,727 |
| | 4 | .4375 | .740 | " | Weatherhead | " | Oil | 245,112 |
| | 5 | .4375 | .729 | " | Aeroquip | " | Air | 227,425 |
| | 6 | .4375 | .745 | " | Weatherhead | " | Air | 189,651 |
| XH-1957 | 1 | .4375 | .726 | OK | Aeroquip | OK | --- | 215,385 |
| Aircraft | 2 | .4375 | .727 | " | Weatherhead | " | --- | 227,495 |
| Cord Wire | 3 | .4375 | .724 | " | Aeroquip | " | Oil | 240,375 |
| | 4 | .4375 | .730 | " | Weatherhead | " | Oil | 190,721 |
| | 5 | .4375 | .728 | " | Aeroquip | " | Air | 257,207 |
| | 6 | .4375 | .729 | " | Weatherhead | " | Air | 231,337 |

## SECTION III
## PROCESS EVALUATION

Past experience with wire braided hose indicated that process improvement, particularly in the braiding operation, would provide a great advance toward meeting impulse requirements. Lengths of hose selected on the basis of superior braid quality invariably gave better results than the average length of hose having a relatively uneven or non-uniform braid.

An observation of any conventional wire braiding operation reveals that the individual strands of wire in each group applied by a single carrier vary considerably in degree of tension. It is known that there are variables that affect this condition such as spring tension, mechanical condition of the carrier, quality of the winding, etc.; but even if the braiding is done under ideal conditions, this variation in tension still persists particularly on the small sizes of hose. Because of this non-uniformity of tension, individual strands of wire continually change position in their particular group to alleviate this condition. This change in position or "cross-over" can be seen quite readily on the braid. It is generally assumed that the number of "cross-overs" is indicative of the braid quality ie, the fewer the "cross-overs" the better the braid.

It was believed that if this variation in tension between individual strands of wire could be eliminated, long and consistent impulse results could be obtained.

On the basis of this premise a considerable portion of the time and monies involved in this contract were expended in improving the braiding and related operations in order to achieve a more uniform braid.

<u>Wire Winding and Braiding</u>

Investigation began with a study of the wire winding machines being used to take the wire from the large spools it is purchased on and wind it in the proper number of ends on to the braider carrier spools. Each reel or spool that Specification 15A wire is purchased on contains approximately 75 pounds of wire. The braider carrier spools each hold approximately 3 pounds of wire.

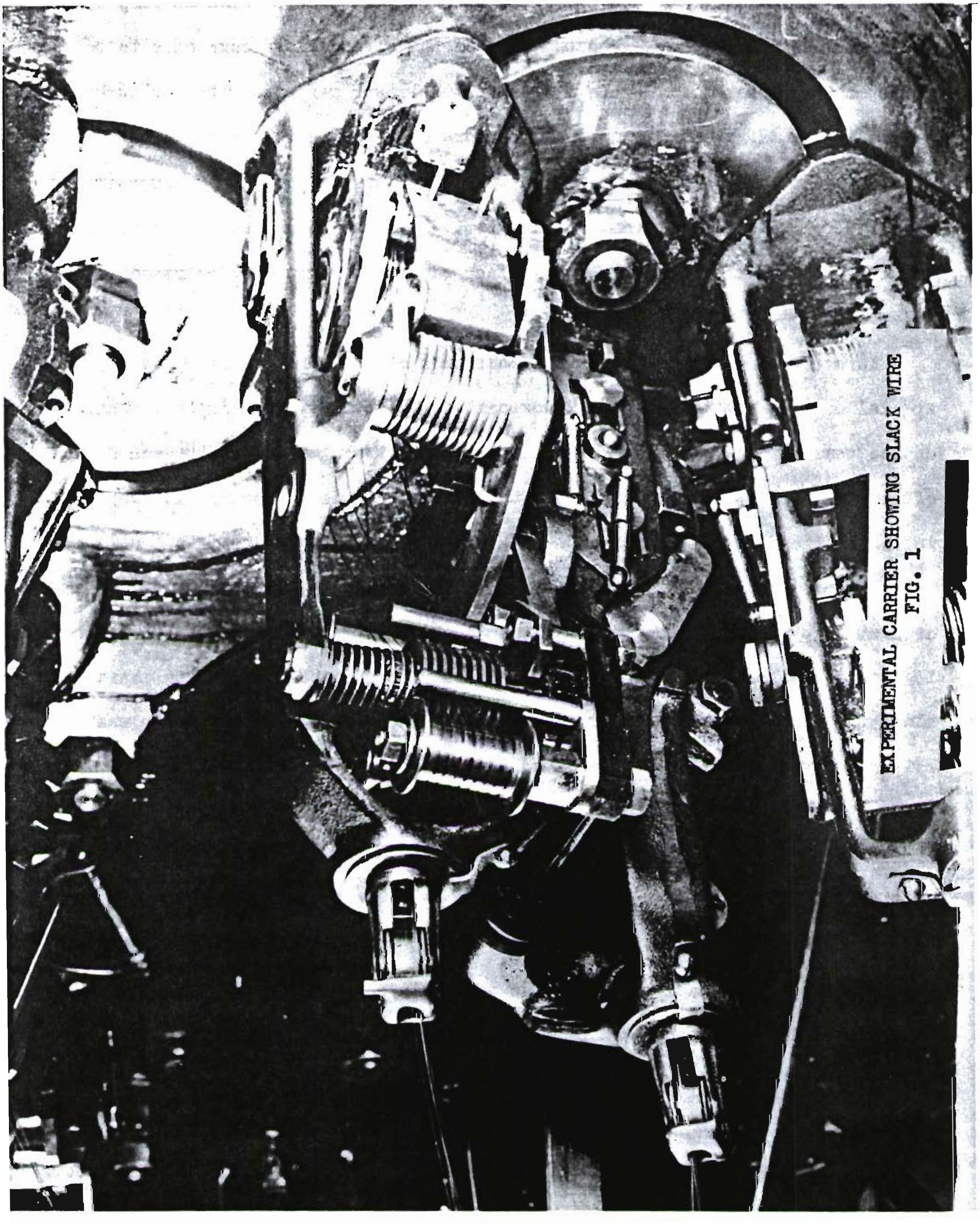
The winding mechanism consists of several let-off devices each of which holds a 75 pound spool of wire. The let-off allows the wire to be pulled from the large spool at a constant tension of 1-1/2 pounds. This is accomplished by a spring actuated friction clutch which is periodically checked to keep tension variations at a minimum. Each end of wire is pulled from the large spool by a set of pinch rollers. All the rollers are driven at the same speed so that each strand of wire being pulled by its set of rollers is equal in length. The strands of wire are fed from the pinch rollers to a rotating braider spool. The braider spool is driven so that it maintains a tension on the wire being applied to it. This tension, which is obtained with a friction clutch, is adjusted so that it does not exceed the tension or grab of the pinch rollers at any time. This operation insures that the individual strands of wire on this braider spool are equal in length. To further insure this equality, the tension of the pinch rollers is set so that the pull required to cause slippage of the wire between the rollers is greater than the strength of the individual strand of wire.

Using this winding apparatus, there is almost no possibility of the individual strands on each braider carrier spool being unequal in overall length. However, it is possible that the length of individual ends of wire wound during any given period of time or number of revolutions may not be equal.

This is possible because the wires are not laid side by side as they are fed on the carrier spools. The bunching of the wires allows some ends to be slack while some ends are taut. This unequality of length per revolution or number of revolutions would result in unequal tensions as the wire is being let off the spools. Of course, this variation in tension would not build up on any particular wire but would fluctuate from wire to wire. In other words, any one wire would vary back and forth from a taut to a slack condition during the course of its release from the carrier spool.

As no method of rectifying this condition at the winders was apparent, a special carrier was built which incorporated a disc tensioning device. This device consisted of a series of friction discs between two of which each strand of wire passed just prior to leaving the carrier. This device worked very well in that all ends of wire leaving the carrier appeared to be equal in tension and very few crossovers were found in the resultant braid. However, during the course of braiding, considerable slack built up on some of the ends in back of the tensioning device while others remained taut. When this condition was first noticed, the slack was taken out and another length was braided. The same condition was again evident. This procedure was repeated several times with the same results. To eliminate the possibility that poor wire winding might be responsible, all the spools were removed from the braider and rewound under careful supervision. This winding was done on the newest machine which was completely checked before the winding was done. The spools were remounted on the carriers and another length was braided. The same slack condition was again encountered (Fig. 1).

Study of the two carriers showed no mechanical defects that might be causing the slack condition. However, careful study of the wire braid itself led to a possible solution of the problem. It was observed on the braid that the individual wires in each group, as applied by each carrier, do not lie in a flat plane as they spiral around the mandrel but travel in a slightly concave band.



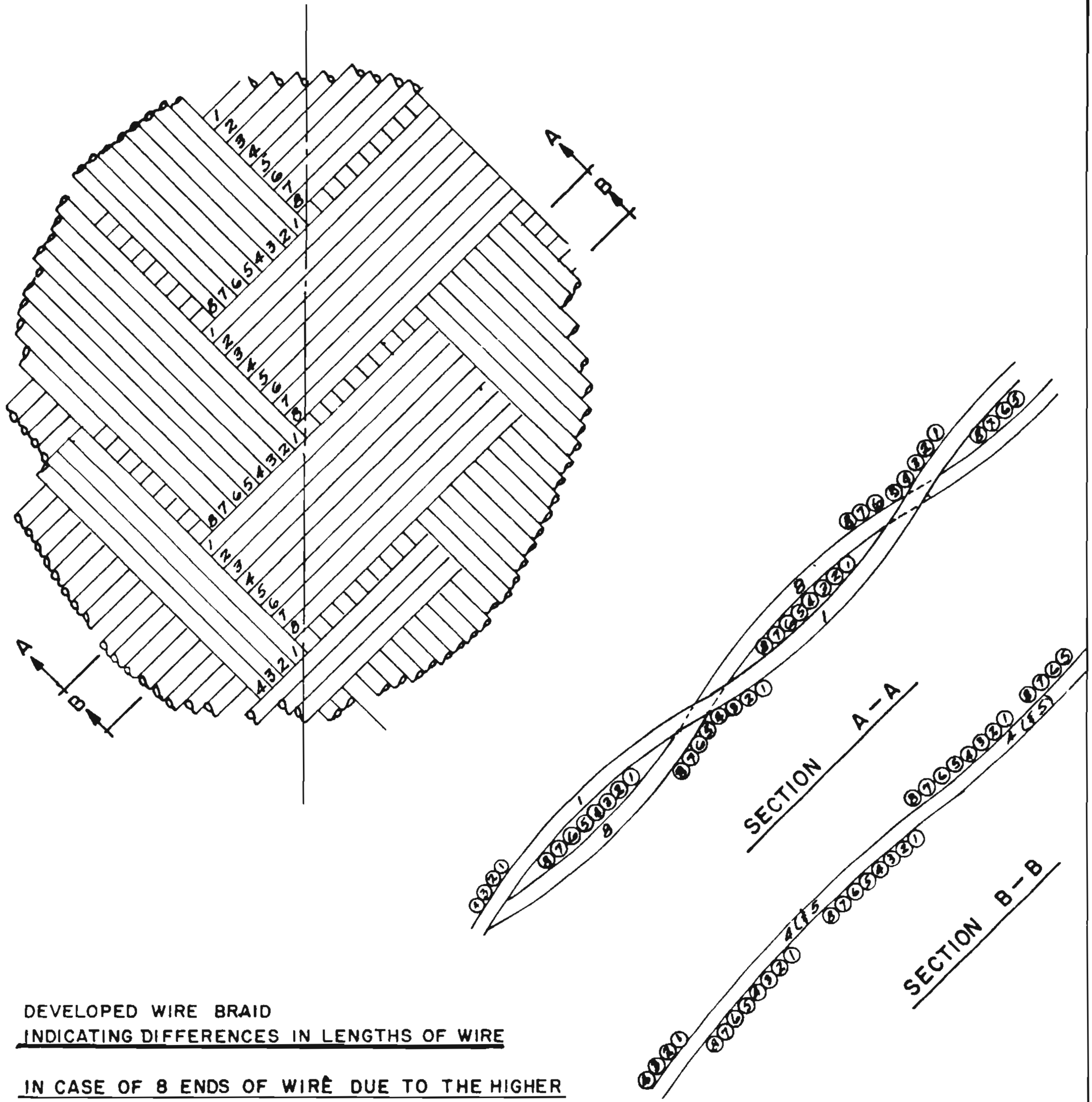
EXPERIMENTAL CARRIER SHOWING SLACK WIRE
FIG. 1

If this be the case, and the data collected seems to substantiate these conclusions, the individual ends in each band vary in length as they travel on different loci with respect to the center line of the hose. In the case of eight ends, #1 and #8 will be equal and the longest, #4 and #5 will be equal and the shortest, #2 and #7 are equal and #3 and #6 are equal and intermediate in length.

A schematic explanation for the concavity of each group of wire is shown on the developed braid drawing (Fig. 2). Sections A-A and B-B illustrate the difference between the wave pitches of the outside (#1 & #8) and the inside (#4 & #5) wires. The wave pitch of the outside wires is greater since these elements travel in the proximity of the crossing of three groups of wire while the inner ends travel over and under only single thicknesses of wire. This condition will become more exaggerated as the percent pack increases. It is possible that on a low percent pack construction the difference in wave pitches and resultant lengths are negligible. However, on the hose concerned, the burst requirements are such that high percent packs are necessary.

To substantiate this theory by actually measuring strand lengths, two groups of wire applied by the special carriers having no crossovers were stripped from a four foot section of braid. These groups were chosen as it was believed that they would show variations in length whereas groups applied by conventional carriers would tend to be equal over a long length, crossovers in the conventional braid occurring to alleviate the tension in the longer ends and to compensate for the slack in the shorter ends. The results obtained are as follows:

| | GROUP A | | GROUP B | |
|---|---|---|---|---|
| Ends # | Color | Length | Color | Length |
| 1 | Black | 68" | Blue | 69-3/8" |
| 2 | (Neutral) | 67-5/8" | (Neutral) | 69" |
| 3 | Blue | 67-9/16" | (Neutral) | 68-13/16" |
| 4 | (Neutral) | 67-1/2" | Red | 68-3/4" |




DEVELOPED WIRE BRAID
INDICATING DIFFERENCES IN LENGTHS OF WIRE

IN CASE OF 8 ENDS OF WIRE DUE TO THE HIGHER WAVE PITCH, NO. 1 & 8 ARE THE LONGEST AND EQUAL IN LENGTH.
NO. 4 & 5 ARE EQUAL AND HAVE THE LOWEST PITCH, HENCE SHORTEST.
NO. 2 & 7 ARE EQUAL AND NO. 3 & 6 ARE EQUAL-AND INTERMEDIATE IN LENGTHS.

| | |
|---|---|
| UNITED STATES RUBBER CO. PASSAIC N. J. | |
| DEVELOPED WIRE BRAIDS — GENERAL LAYOUT | |
| DATE 4-25-52 | DRAWN BY Cav |
| APPROVED BY T.E. | CHECKED BY DEP |

FIG. 2

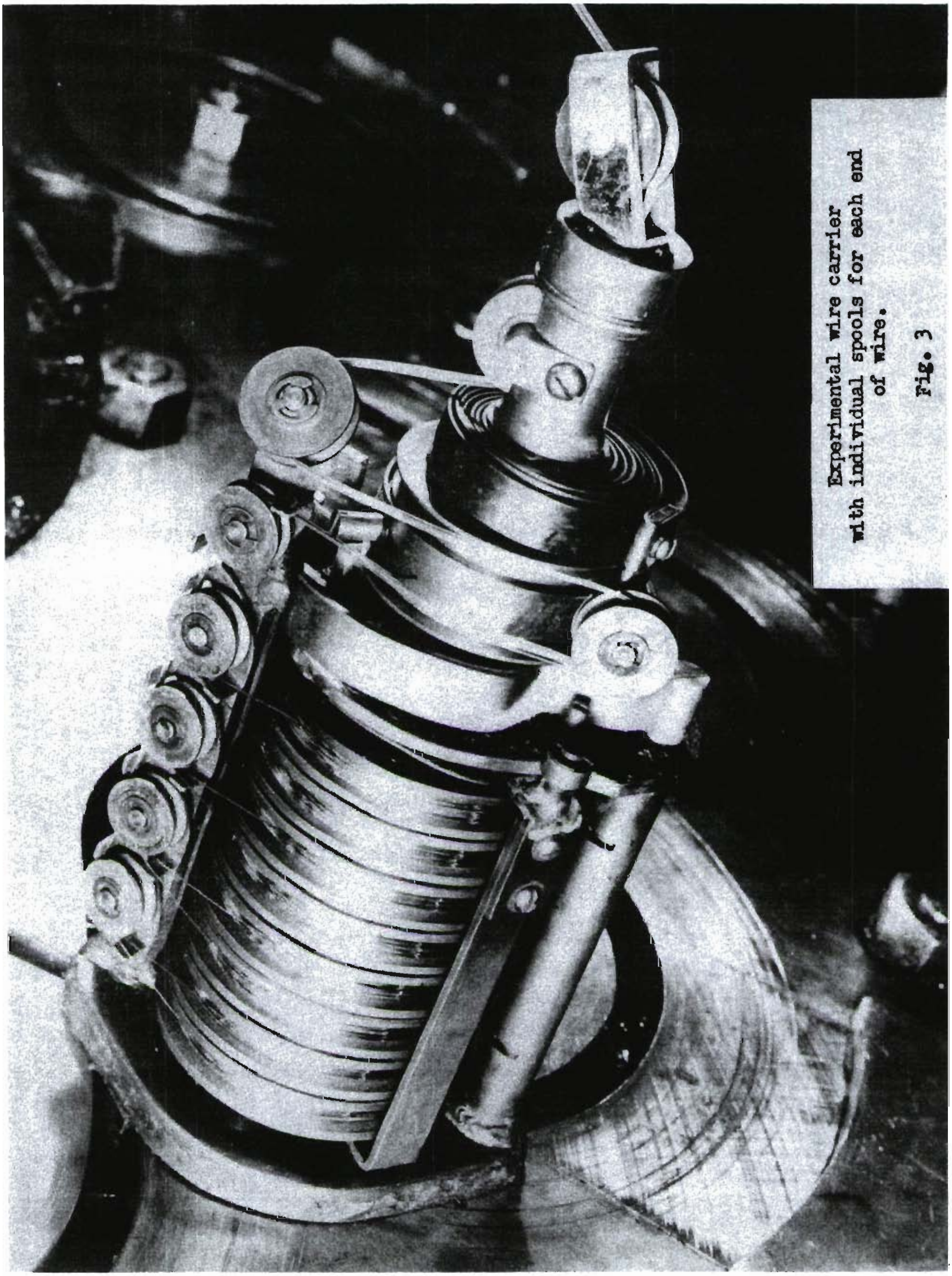
| Ends # | GROUP A Color | Length | GROUP B Color | Length |
|---|---|---|---|---|
| 5 | Green | 67-1/2" | Green | 68-3/4" |
| 6 | Red | 67-1/2" | (Neutral) | 68-13/16" |
| 7 | (Neutral) | 67-11/16" | (Neutral) | 69" |
| 8 | (Neutral) | 67-13/16" | Black | 69-7/16" |

Due to the difficulty encountered in stripping the two groups from the four foot section of braid, only the position of the colored wires was definitely established. The lengths obtained on the neutral wires have been inserted to form the pattern shown. Even if the pattern of lengths shown is in error, the data definitely established that there exists a variation in lengths which is the prime concern.

On the basis of this determination a new carrier design was developed which embodied the use of separate let-off spools for each end of wire. By separately braking each spool it was believed that uniform tension could be obtained even though different lengths of wire were required from each spool to form the braid.

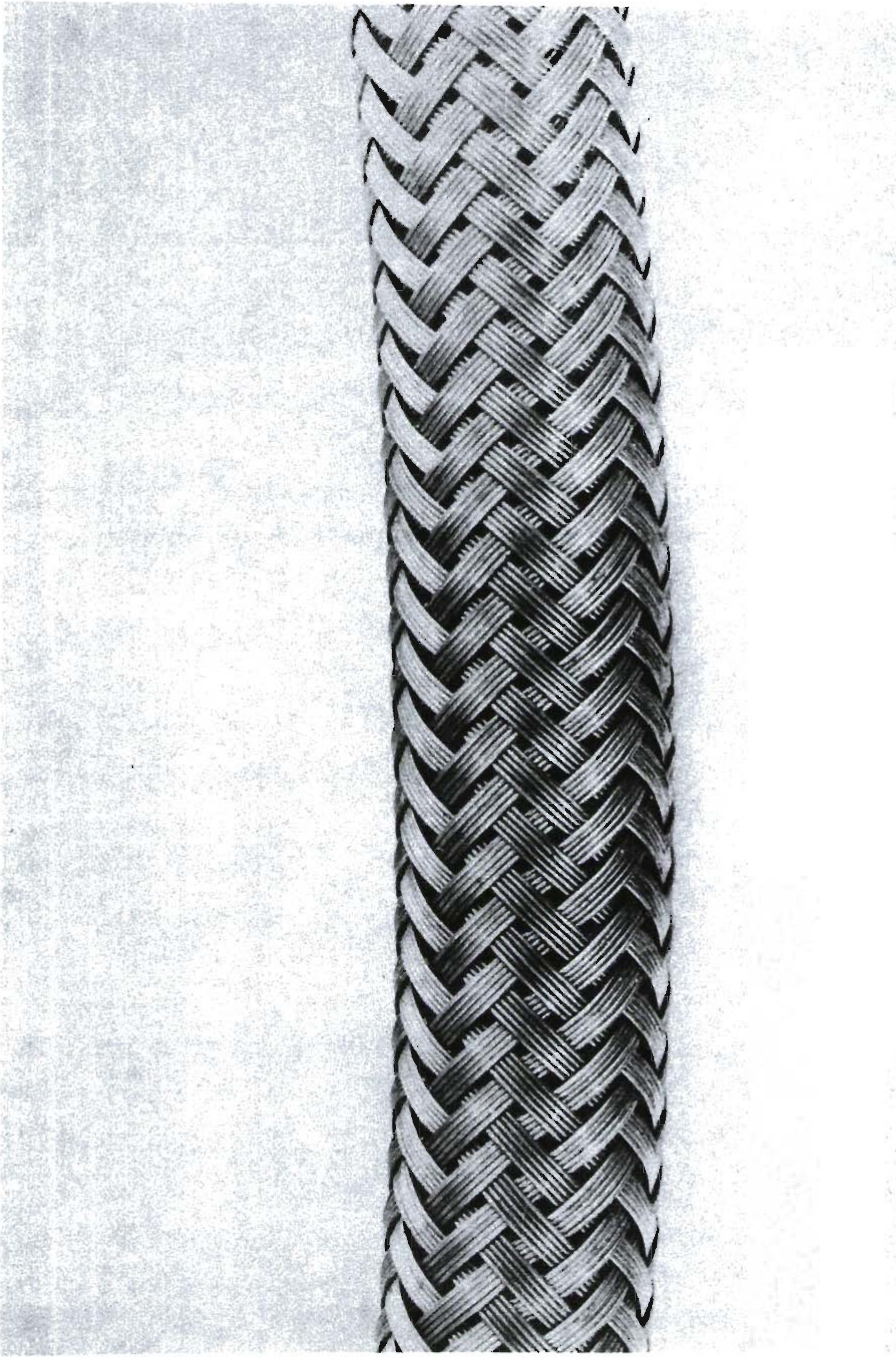
Two trial carriers were fabricated and evaluated. These appeared to do the job intended and with a few modifications, twenty-two additional carriers were made. Figure #3 is a photograph of this wire carrier incorporating the individual spool let-off mechanism.

Trials with these carriers were very promising. The wire braided with uniform tension between all ends and no crossovers were found in the finished braid. Figure #4 shows the uniform braid obtained using these carriers. One disadvantage, however, is the job of threading up these units as compared to the conventional carrier. Its complexity makes this job take about five times longer than normal. This makes the practicability of these carriers questionable, but further simplification of design is feasible.



Experimental wire carrier
with individual spools for each end
of wire.

Fig. 3



Perfect wire braid
Produced with special carriers

Fig. 4

Initial braiding trials were conducted using five ends of wire on each carrier spool so that the braiding could be done directly on a 7/16" O.D. hose mandrel with approximately 90% wire pack simulating actual 7/16" I.D. hose conditions. This procedure simplified the evaluation. The braid shown in figure #4 was produced in this manner.

In order to expedite the fabrication of hose samples after the completion of the preliminary braiding trials, samples of 5/16" I.D. size -6 Specification MIL-H-5017 hose were made using the five end wire set-up to avoid rewinding wire for the seven ends necessary to make the 7/16" I.D. hose. Samples of this hose, XH-1732 shown below, were produced using the special braider carriers. Additional samples of hose similar in construction, XH-1532, were produced using conventional braider carriers. Burst and impulse tests were conducted on both constructions. These results are shown below.

<u>XH-1732</u> MIL-H-5017, Size -6, 5/16" I.D.

| | |
|---|---|
| Tube: | BN-40507-G-2. Finished gauge .070"<br>Extruded 23/64" I.D. x .095" gauge wall<br>Semi-cure 15' @ 30# steam |
| Cement: | Wash with Solvesso and apply 1 coat P-784 cement. |
| Wire Braid: | .012" dia. (Spec. 15A wire), 5 ends, 24 S.M., 1-1/8" pitch 33/64" O.D. |
| Layer: | M-4779, 0.032" gauge. |
| Wire Braid: | .012" dia. (Spec. 15A wire) 5 ends, 24 S.M., 1-1/8" pitch 39/64" O.D. |
| Layer: | M-4779 .016" gauge. |
| Breaker Ply: | 7/3-1 end, 1-1/8" pitch |
| Cover: | 4650 .040" gauge extruded 23/32" O.D. |
| Cure: | Spiral nylon wrap 60' @ 50# steam. |

<u>XH-1532</u> MIL-H-5017, Size -6, 5/16" I.D.

Construction identical to XH-1732 except hose samples produced using conventional braiding equipment.

<u>Test Results</u>

<u>Impulse Test</u> 3000 P.S.I. operating with 150% peak.

| | | | |
|---|---|---|---|
| XH-1732 | Unaged Sample #1 | 142,000 cycles | Hose Burst |
| | " " #2 | 155,000 " | " " |
| | " " #3 | 172,000 " | " " |
| XH-1532 | Unaged Sample #1 | 113,000 cycles | Hose Burst |
| | " " #2 | 152,000 " | " " |
| | " " #3 | 159,000 " | " " |

## Burst Test

| | | |
|---|---|---|
| XH-1732 | Sample #1 | 18,500 P.S.I. |
| | " #2 | 18,000 " |
| XH-1532 | Sample #1 | 17,800 P.S.I. |
| | " #2 | 18,300 " |

The test results do not indicate a marked difference between the two hose samples. Although the XH-1732 samples show an average of 25,000 cycles more than the XH-1532 hose made using conventional equipment, this difference is not considered significant since variations in impulse results are normally quite large. Even though the comparison did not indicate a great improvement, it is quite possible that more testing will indicate that hose braided with individual strands of wire under equal tension will have more consistent impulse life. Hose giving consistent impulse results at the high life level obtained in these tests would be very desirable.

## Conclusions and Recommendations

It is concluded from the work done that with the proper choice of tube, layer, and cover compounds in combination with commercial grade high tensile hose reinforcement wire, and provided the reinforcement design follows the principles developed, hose can be manufactured using conventional equipment to meet the requirements of Specification MIL-H-5017 size -8 hose.

Since the completion of this contract, this statement has been borne out as this company is now qualified and is manufacturing hose in -8 and other sizes to meet the requirements of Specification MIL-H-5512 without exceptions.

Furthermore in order to maintain a satisfactory quality level on this hose, it is mandatory that rigid quality controls and inspection are applied to the materials and operations involved. Proper maintenance of equipment, particularly the braider is of great importance.

The experimental work done with the special braider carriers indicated that equal tension braiding does not substantially improve the impulse life of hose.

However, there is a possibility that more impulse test data will indicate a greater uniformity of results. Unfortunately, insufficient funds were available on this contract to fabricate and test more hose samples.

This company's recent production experience with the -6 5/16" I.D. and -8 7/16" I.D. sizes indicates that the average impulse life of these sizes is sufficiently in excess of the 100,000 cycle minimum so that variations of the order encountered can be tolerated but the average impulse life of sizes -10 and larger is much lower and on these sizes they can make the difference between good and bad hose.

It is the opinion of the investigators that further evaluation of the experimental braider carriers on the critical sizes is desirable. However, in order to properly do this it would be necessary to run several thousand feet of hose using this equipment and compare the impulse test results obtained on a large number of samples selected from this hose with similar samples selected from an equal amount of hose produced using conventional equipment. This is too costly an experiment for this company to conduct at its own expense and further work with the special carriers is not contemplated.

In their present form the special carriers are not entirely practical from a production standpoint in as much as the time required to thread the wire in these carriers is several times that necessary to thread the standard unit. However, it is quite possible that the design can be adjusted to eliminate this extra labor. It is our opinion that the practicality of the experimental carriers at their present stage of development should not obstruct the consideration of further experimental work with them.

## APPENDIX

### Recipes

#### BN-4636

| Ingredient | Wt. lbs. |
|---|---|
| Buna N Master Batch BN-MM-931 | 240. |
| Buna S Master Batch S-MM-939 | 63. |
| Zinc Oxide | 9.5 |
| S-66 Kosmobile Black (MPC) | 50. |
| Pelletex (SRF) | 75. |
| Altax | 3.8 |
| Agerite White | .5 |
| TP-90-B | 40. |
| Sulfur | 3.3 |
| | 485.1 |

#### BN-MM-931

| | |
|---|---|
| Paracril B5 | 262. |
| Pelletex (SRF) | 100. |
| Estac #17 | 10. |
| | 372. |

#### S-MM-939

| | |
|---|---|
| GRS | 200. |
| Pelletex (SRF) | 200. |
| Estac #17 | 10. |
| | 410. |

#### 40507-G-2

| | |
|---|---|
| 40515A Masterbatch | 45. |
| 40516A Masterbatch | 213. |
| Zinc Oxide | 8.5 |
| Pelletex (SRF) | 50. |
| Kosmobile S-66 (MPC) | 50. |
| Philblack O (HAF) | 25. |
| Agerite White | 1.3 |
| Esen | 1.3 |
| TP-90-B | 38. |
| Altax | 3. |
| Sulfur | 3. |
| | 438.1 |

#### 40515A

| | |
|---|---|
| GRS-489 | 200. |
| Pelletex (SRF) | 200. |
| TP-90-B | 10. |
| | 410. |

## 40507-G-3

**Recipes**

| Ingredient | Wt. lbs. |
|---|---|
| GRS-1015A | 7.5 |
| Paracril BJ | 35.5 |
| Zinc Oxide | 2.1 |
| Pelletex (SRF) | 50. |
| Agerite White | .4 |
| TP-90-B | 11. |
| Altax | .8 |
| Sulfur | 1.5 |
| | 108.8 |

## 40516A

| | |
|---|---|
| Sarna Krynac | 300. |
| Pelletex (SRF) | 115. |
| TP-90-B | 12. |
| | 427. |

## M-4779

| | |
|---|---|
| Neoprene GN | 180. |
| Keystone Whiting | 225. |
| Kosmobile S-66 | 50. |
| Estac #17 | 10. |
| Pine Tar | 10. |
| B-L-E | 1. |
| Circo Oil | 10. |
| R-54 (Zinc Oleate) | 5. |
| Maglite D | 10. |
| Zinc Oxide | 5.4 |
| Sulfur | 5. |
| | 511.4 |

## M-4650

| | |
|---|---|
| Neoprene GN | 206. |
| Zinc Oxide | 10. |
| Magnesium Carbonate | 5. |
| Philblack A | 150. |
| Plasticizer SC | 30. |
| DiButyl Sebacate | 30. |
| Seedine | 6. |
| Altax | 2. |
| Neozone D | 5. |
| Sulfur | 4.2 |
| | 448.2 |

# MATERIAL SPECIFICATIONS

## Standard 15-A Wire

| | |
|---|---|
| Type of Wire: | Hard drawn steel |
| Finish: | Liquor (Straw color) |
| Shape: | Round |
| Gauges: | .012" and .015" |
| Tensile: | 350,000 - 400,000 P.S.I. |
| Gauge Limits: | .012" ± .0003"<br>.015" ± .0003" |
| Brittleness: | In no case shall wire be brittle. It must be sufficiently flexible to bend around a mandrel 4 times the diameter of the wire without showing signs of fracture. |

## Swedish Steel Wire

Same as above except Swedish Steel.

## Aircraft Cord Wire

Same as above except drawn from ground rod.

Tensile: 300,000 - 350,000 P.S.I.

## 7/3 Yarn

| Size/Ply | Tensile Strength | Single End Yds/lb. | Gauge | Grade of Yarn | Color |
|---|---|---|---|---|---|
| 7/3 | 9.0 | 1910 | .0245" | Karded American | White |